APPLICATION FOR PATENT

TITLE: CONFOCAL WAFER-INSPECTION SYSTEM

This application is a Continuation of PCT/IL02/00841 filed October 21, 2002, the contents of which are incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates to the field of checking the height of small objects, and more specifically, of three-dimensional objects by using height measurement techniques.

BACKGROUND OF THE INVENTION

A "bump" is a three-dimensional shape (half sphere or rectangular) salient, made of solder or gold located on the face of a microelectronic chip. The bump exists in some chips and substitutes as leads by means of which the component is connected to the printed circuit when the bumps are soldered to the board. The bump shape is usually a half ball alike. A chip can contain a large number of bumps, which should be of the same height in order to connect all of them to the board at the same time. Actually, there are differences between the heights of the various bumps, as a result of the production process. Only small height differences can

be allowed, and these must be within the tolerance limits. Therefore the height of each bump must be checked.

Various systems for wafer-inspection are known and the main disadvantage of all those systems is a low accuracy in height measurement. Therefore, the main object of the present invention is that it uses a Confocal Height Measuring System (CHMS) to achieve accurate height measurement.

Confocal Height Measuring System (CHMS) is assembled from a confocal imaging optical setup with chromatic aberration focusing lens, a light source, an optic head that separates the light source to its basic wavelength and a spectrometer.

The confocal imaging optical setup is an optical setup for imaging a point of light source into a sharply focused second point and then reversing the image from the second point onto a tiny spatial filter. Such an optical setup is absolutely blind for all the space except for the sharply focused second point. Field extension can be obtained by stretching the chromatic aberration of the focusing lens of the setup. The new setup,

with such a lens, is assembling of infinity of purely confocal systems, one for each wavelength.

Since each wavelength has a different focus length, said setup can be used as height-measuring device to measure the height of a surface point. A white light beam is separated to its basic wavelength beams by the optic head and each beam illuminates the surface. The illumination is reflected back through the confocal imaging optical setup to the spectrometer. Only one wavelength is passed the confocal imaging optical setup, according to height of the surface, which matches the focus length. The wavelength is detected by the spectrometer and translated to the height of the surface point according to a calibration table.

Confocal imaging optical setup and confocal height measuring system are described in patent application, with a French title: "Dispositif de microstratigraphie optique" - national registration number : FR9510401 and publication number : 2 738 343 and patent application, with a French title: "Dispositif de tomographie optique en champ coloré" - national registration number : FR9402489 and publication number : 2 716 727.

Since the low accuracy - in height measurement - is the main disadvantage of the known systems, there is a recognized need for, and it would be highly advantageous to have, a system and a method for wafer-inspection that uses confocal height measuring system for checking the accurate height of bumps for comparing bumps on a wafer.

SUMMARY OF THE INVENTION

The present invention is a confocal wafer-inspection system.

According to the teachings of the present invention there is provided a confocal height measuring system wafer-inspection system including:

(a) a table, to put on a wafer for inspection, this table has two vertical degrees of freedom, enables XY axis movements;

(b) a movement-means for move the table along the vertical degrees of freedom;

(c) a confocal height measuring system, perpendicular to the table, for measuring the range to a point on a surface of the inspected wafer, enables to recognize changes in surface altitude while the wafer moves with the table; and

(d) a computer operative for:

(i) holding a bumps map of the inspected wafer;

(ii) controlling the movement means;

(iii) moving the table so that the measuring point of the confocal height measurement system crosses each bump of the wafer;

(iv) storing the height profile of each bump;

(v) comparing the height profiles and checking each height profile according to predetermined criteria; and

(vi) display results.

By one preferred embodiment the wafer-inspection system, further includes:

(e) a microscope, integrated with the confocal height measurement system, to observe the inspected wafer surface; and

(f) a first camera for photographs the observed surface.

By second preferred embodiment the wafer-inspection system, further includes a vertical movement means for elevate and lower the microscope and the confocal height measurement system.

By another preferred embodiment the wafer-inspection system, further includes a second camera for scanning the inspected wafer, than the image or images of the scanning are used by the computer to recognize bumps, the computer stores location of the recognized bumps and built a bumps map to be held by the computer.

By another preferred embodiment the second camera of the wafer-inspection system is a digital camera.

By another preferred embodiment the second camera of the wafer-inspection system is a line-scan camera.

By yet another preferred embodiment of the wafer-inspection system, the vertical movement means enables elevate and lower the second camera.

According to another aspect of the present invention, it provides a method for accurate inspection of a wafer, includes the following steps:

(a) obtaining a digital image of a wafer, using one of the following techniques :

(i) photographing the whole wafer; or

(ii) scanning sectors or lines of the wafer and composing a wafer image;

(b) mapping location of bumps on the wafer, by recognizing bumps in the wafer image according to predetermined criteria;

(c) planning a bumps-track line, wherein the bumps-track line crosses each bump on the wafer, at least one cross each bump;

(d) using a confocal height measurement system, located perpendicular to the wafer, to measure height changes along the bumps-track line;

(e) obtaining height profile of each bump, from the height changes along the bumps-track line; and

(f) comparing and checking bumps height profile.

BRIEF DESCRIPTION OF THE FIGURES

The invention is herein described, by way of example only, with reference to the accompanying drawings. With specific reference now to the drawings in detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of the preferred embodiments of the present invention only, and are presented in the cause of providing what is believed to be the most useful and readily understood description of the principles and conceptual aspects

of the invention. In this regard, no attempt is made to show structural details of the invention in more detail than is necessary for a fundamental understanding of the invention, the description taken with the drawings making apparent to those skilled in the art how the several forms of the invention may be embodied in practice.

In the figures:

Figure 1 illustrates the confocal optic setup.

Figure 2 illustrates an embodiment of the confocal wafer-inspection system.

Figures 3a and 3b illustrate the way of obtaining profiles of bumps.

DESCRIPTION OF THE PREFERED EMBODIMENTS

The present invention is a confocal wafer-inspection system.

The system has a table with two vertical degrees of freedom enables a movement means to move the table in XY axis. A wafer is laying on the table and a confocal height measurement system, a microscope, a first camera and a second camera are installed perpendicular to the table, held by a horizontal movement means. A computer controls the vertical movement means and the horizontal

movement means. The microscope and the confocal height measurement system are aimed to the same point.

An inspected wafer lies down on the table. The computer controls the movement of the table by the movement means, enables each point of the wafer surface being under the aim point. The microscope observes the wafer's surface and the first camera photograph the view and the image is transferred to the computer, which display the image on the screen. The image is used by an operator of the system to overview the surface and enables to determine the criteria for recognizing bumps.

The second camera scans the wafer and recognizes the location of all bumps on the wafer surface. The computer receives the scanned image, builds a map of bumps location and designed a bumps-track along the wafer surface, which crosses at least one time each of the bumps. The computer leads the table, by means of the vertical movement means, so that the bumps-track passes down the aim line along the whole bumps-track. The confocal height measurement system continually measures the wafer surface height and transfers information to the computer. When the aim line crosses a bump, the computer stores the height profile of the bump. The computer compares between bumps height or checks bumps

profiles according to predetermined criteria or both and enables to have the results by any output device.

The principles and operation of the confocal wafer-inspection system according to the present invention may be better understood with reference to the drawing and the accompanying description.

As used herein in the specification and in the claims section that follows, the term " confocal height measurement system" and the like refer to the system that uses confocal technique to measure height changes on a surface by measuring distance from a constant point. The confocal height measuring system was described in details in the background section and in Figure 1.

Referring now to the drawing, Figure 1 illustrates the confocal optic setup. A confocal imaging optical setup is an optical setup for imaging a point of light source "S" **11** through a lens **12** into a sharply focused second point "S1" **13** and then reversing the image from the second point **13** onto a splitter **14** that reflects the image onto a tiny spatial filter "S2" **15**. Such an optical setup is absolutely blind for all the space except for the sharply focused second point **13**. Field extension can

be obtained by stretching the chromatic aberration of the focusing lens **12** having a setup with an infinity of purely confocal systems, one for each wavelength with a different sharply focused point **13a**, **13b**, **13c** and so on.

The field extended setup can be use as a height-measuring device to measure the height of a surface point. A white light beam is separated to its basic wavelength beams and illuminates, from light source **11**, the surface through the chromatic stretched lens **12**. Each color has a different focusing point, **13a**, **13b** or **13c**. The illumination is reflected back through the splitter **14** onto the tiny spatial filter **15**. Each color has a different sharply focused point; the first color has a first sharply focused point **13a**, the second color has second sharply focused point **13b** and the third color has a third sharply focused point **13c**. Only one color arrives to the filter **15**, according to height of the surface, which matches the focus length. If the surface height matches the first sharply focused point **13a**, then the first color is detected, if the surface height matches the second sharply focused point **13b** the second color is detected and so on. The color is detected by a spectrometer and translated to the height of the surface point according to a calibration table.

Figure 2 illustrates an embodiment of the confocal wafer-inspection system. A table **21** with two vertical degrees of freedom enables a movement means **22** to move the table **21** in XY axis. A wafer **23** is lay on the table **21** and a confocal height measurement system **26**, a microscope **30**, a first camera **28** and a second camera **29** are installed perpendicular to the table **21**, held by a horizontal movement means **25**. A computer **24** controls the vertical movement means **22** and the horizontal movement means **25**. The microscope **30** and the confocal height measurement system **26** are aimed **27** to the same point.

An inspected wafer **23** lies down on the table **21**. The computer **24** controls the movement of the table **21** by the movement means **22**, enables each point of the wafer **23** surface being under the aim point **27**. The microscope **30** observes the surface of the wafer **23** and the first camera **28** photograph the view and transfer the image to the computer **24**, which display the image on the screen. The image is used by an operator of the system to overview the surface and enables to determine the criteria for recognizing bumps.

The second camera **29** scans the wafer and recognizes the location of all bumps (not shown) on the wafer surface. The computer **24** receives the scanned image, builds a map of bumps location and designed a bumps-track along the wafer surface, which crosses at least one time each of the bumps. The computer **24** leads the table **21**, by means of the vertical movement means **22**, so that the bumps-track passes down the aim line **27** along the whole bumps-track. The confocal height measurement system **26** continually measures the wafer **23** surface height and transfers information to the computer **24**. When the aim line **27** crosses a bump (not shown), the computer **24** stores the height profile of the bump. The computer **24** compares between bumps height or checks bumps profiles according to predetermined criteria or both and enables to have the results by any output device.

Figure 3 illustrates the way of obtaining profiles of bumps. Figure **3a** shows a part of wafer surface **23** with bumps **31** on it. The wafer surface **23** moves according to the computer **24** controls along the bumps-track so that aim points **27** crosses the bumps **31**. The confocal height measurement system **26** continually measures the bumps **31** height and transfers information to the computer **24**. Figure **3b** is a graphic illustration of the confocal height measurement system **26** measurements,

which contains bumps height profiles **32**, these profiles will be compared by the computer **24** or checked according to predetermined criteria.

Although the invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art, accordingly, it is intended to embrace all such alternatives, modifications and variations that fall within the spirit and broad scope of the appended claims.